https://doi.org/10.7075/TJFS.202406_39(2).0001

Research paper

Reproductive Phenology of *Garcinia kola* (Heckel) in a Humid Forest Plantation

Henry-Onyebuchi Okonkwo,[1] Godwin-Ejakhe Omokhua,[2] Uzoma-Darlington Chima[2]

ABSTRACT

The correlation between phenology and climate makes them useful indicators of the effects of climate warming. In this study we assessed the reproductive phenology of *Garcinia kola*, an evergreen multipurpose fruit tree species, in relation to underlying climate cues. The assessment was carried out within an artificial mono-plantation of *G. kola* propagated from seeds at the Swamp Forest Research Station of the Forestry Research Institute of Nigeria in Onne Rivers State, Nigeria. Phenological events of the plantation were observed over a period of three reproductive seasons, sampling 19 trees comprising ten female, six male, and three hermaphrodite trees. Collected phenological data included onset and duration of reproductive rest, flower bud initiation and duration, duration of bud growth, bud opening (anthesis) and fertilization, fruit maturity, onset of the reproductive season, flowering intensity, and the reproductive cycle. Variation of climate and flowering intensity was analyzed using analysis of variance, correlation and t-test analysis. We found that the onset of reproductive rest in the plantation ranged from May to August due to significant differences ($p \leq 0.05$) in rainfall patterns throughout the reproductive seasons; and that temperature cues determined flowering intensity. The onset of reproduction in the plantation exhibited a strong positive correlation with temperature ($r = 0.76$) and sunshine hours ($r = 0.78$); conversely, onset of reproduction showed a strong negative correlation with rainfall ($r = -0.73$). Flowering intensity during the drier months was lower than during the rainy season. No significant difference ($p \geq 0.05$) in temperature and flowering intensity was observed between reproductive seasons. These observations indicate that variation in rainfall and temperature influenced by climate warming may impact flowering and reproduction in the plantation and that the productivity of *G. kola* in the plantation is susceptible to the effects of climate change.

Keywords: flowering-intensity, rainfall, temperature, sunshine-hours, phenology of *Garcinia kola*

Okonkwo HO, **Omokhua GE**, **Chima UD. 2024.** Reproductive Phenology of *Garcinia kola* (Heckel) in a Humid Forest Plantation. Taiwan J For Sci 39(2):83-93.

---

[1] 尼日利亞翁內河州林業研究所沼澤森林研究站 Swamp Forest Research Station, Onne Rivers State, Forestry Research Institute of Nigeria.

[2] 哈科特港大學農學院林業和野生動物管理系 Department of Forestry and Wildlife Management, Faculty of Agriculture, University of Port Harcourt, Choba, Rivers State, Nigeria.

Corresponding author, Henry Onyebuchi Okonkwo, E-mail: richychrist4ever@gmail.com

Received February 2024, Accepted March 2024. 2024年2月送審2024年3月通過。

研究報告

藤黃在潮濕人工林的生殖物候學

Henry-Onyebuchi Okonkwo,[1] Godwin-Ejakhe Omokhua,[2] Uzoma-Darlington Chima[2]

摘 要

物候與氣候的相關性使它們成為氣候暖化影響指標。本研究試圖評估常綠多用途果樹種*Garcinia kola*的繁殖物候學與氣候的關係。在奈及利亞奧內河州奈及利亞林業研究所沼澤森林研究站的單一樹種人工林中進行，所有林木均透過種子繁殖而來。人工林的物候表徵在三個生殖季節內進行研究，共採樣了 19 棵樹，其中包括 10 棵雌樹、6 棵雄樹和 3 棵兩性樹。收集的物候學資料包括生殖起迄和持續時間、花芽起始和持續時間、芽生長持續時間、芽開放(開花)和受精、果實成熟、生殖季節起始期、開花強度和生殖週期。氣候和開花強度透過變異數、相關性、t 檢定和回歸分析進行了檢測。發現人工林內的生殖季節在 5 月至 8 月之間波動，乃因不同生長季之間降雨模式呈顯著差異所致($p \leq 0.05$)，氣溫決定了開花強度。人工林生殖開始季節與氣溫($r = 0.76$)及日照時數($r = 0.78$)之間存在強烈正相關；而生殖起迄期與降雨量($r = -0.73$)之間存在強烈負相關。相較於乾燥的月份，開花強度低於雨季。不同的生殖季之間，氣溫和開花強度無顯著差異($p \geq 0.05$)。所有證據顯示氣候暖化所引起的降雨和氣溫變化，可能會影響人工林的開花和繁殖。因此，*G. kola* 在人工林中的生產力容易受到氣候變遷所影響。

關鍵詞：開花強度、降雨量、溫度、日照時數、*Garcinia kola* 物候學

Okonkwo HO, **Omokhua GE**, **Chima UD**. **2024**. 藤黃在潮濕人工林的生殖物候學。台灣林業科學39(2):83-93.

INTRODUCTION

The sensitivity of phenology to climate variability makes it an important indicator of the impact of climate warming (IPCC 2014, Rosemartin et al. 2014). The impact of climate warming on reproductive phenology, particularly in the case of flowering plants, is most conspicuous, since we rely on their fruits and seeds for food. The late or early arrival of fruits or seeds (often associated with climate warming) is evident to the average individual, which reinforces the crucial role that reproductive phenology plays in our lives while highlighting the seriousness of climate warming.

Tropical phenology is thought to be primarily precipitation dependent, but there are also tropical species known to exhibit temperature dependent phenology (Borchert 1998, Morellato et al. 2000, 2013). Climate warming induced changes in precipitation and temperature patterns must be correlated to phenology in order to understand the implications for the reproduction of tropical plants (Rosenzweig et al. 2008).

Understanding the impact of climate warming on the reproductive phenology of many tropical species remains obscure due to paucity of long term phenological studies (Bradley et al. 2011). Climate warming is already changing the known phenological patterns of many species (Hagen et al. 2012). It is essential to understand the implications of these shifts on the future reproductive behaviour of populations as well as the patterns of the changes and their interrelatedness with other plants and animals.

Garcinia kola (Heckel) is an evergreen tropical rainforest species that occurs in West and Central Africa, with Nigeria and Cameroon being the regions with the highest endemism (Isawumi 1993, Manourova et al. 2019). *G. kola* is susceptible to the effects of climate warming since it is mostly found in wet or coastal forests, lowland rainforests, and derived savannah in West Africa. This distribution area is significantly impacted by rainfall and temperature (Agwu et al. 2020). Recent research by Agwu et al. (2020) indicates that climate warming has reduced the range of *G. kola* range in West Africa. In Nigeria, *G. kola* is most commonly found in lowland rainforests and coastal (wet) forest regions. Keay et al. (1989) recorded the species in Ogun State (Omo Forest Reserve), Edo State (Okomu Forest Reserve), Anambra State (Nnewi), Rivers State (Degema), and Cross-River state (Ikom). Onyekwelu et al. (2015) recorded *G. kola* in derived savannah ecosystems in an assessment of fruit trees within rainforest and derived savannah ecosystems in Ondo State.

There remains a need to understand the reproductive phenology of *G. kola*, the environmental cues, and patterns of response to climate warming. There is likelihood that the species response could result in outright inability to reproduce. The paucity of information on the phenology of *G. kola* (similar to many tropical species) means that we do not know to what extent the phenology has already been altered by warming climate. In this investigation we assessed the phenoevents of the reproductive phenology of *G. kola* in relation to underlying climatic cues in a humid forest plantation in Onne, Rivers State, Nigeria.

MATERIALS AND METHODS

Study plantation

The artificial mono-plantation of *G. kola* is located in the Swamp Forest Research Station of the Forestry Research Institute of Nigeria (FRIN) in Onne Rivers State, Nigeria. The station records mean annual rainfall of 2,400 mm, relative humidity of 78%, and mean annual temperature of 26℃. The plantation is located at 4° 42’ 10.32” N 7° 10’ 32.46” E, has a perimeter of 586 m and an area of 6,045 m^2. The plantation of 103 trees in 5 × 5 m spacing was started from seed planted in 1992 and 2009. The plantation is trioecious with invariant female trees, inconstant male trees, and hermaphrodite trees indicating evolution toward dioecy. The area is a mangrove transition forest zone with soil pH between 4.65 ± 0.21 (topsoil) and 5.01 ± 0.25 (subsoil, depth of 0-15 cm), 82% sand, 6% silt, and 12% clay (Okonkwo et al. 2020a; Okonkwo et al. 2022).

Phenological studies

The phenology and phenoevents of the plantation were studied over a period of three reproductive seasons (2018/19, 2019/20, and 2020/21). Ten female trees, six male trees, and three hermaphrodite trees were sampled for the study. Data on the following phenoevents and seasons were collected weekly:

	Phenoevent	Description
1.	Reproduction	Presence of flower or/and fruits.
2.	Reproductive rest onset	Onset of flowering and fruiting off-season.
3.	Reproductive rest duration	Duration of flowering and fruiting off-season.
4.	Reproductive onset	Onset of flowering/flower bud initiation
5.	Duration of flower bud initiation	Duration of flowering onset
6.	Bud opening (anthesis) and duration	Flower bud opening onset and duration
7.	Fertilization onset and duration	Initiation and duration of flower fertilization
8.	Flowering intensity	Mean number of flower buds per inflorescence
9.	Reproductive season	Flowering and fruiting season.
10.	Reproductive cycle	Lasts from flowering initiation to the end of flowering/fruiting
11.	Wet season	Lasts from May to November
12.	Dry season	Lasts from December to April
13.	Male inconstancy	Percentage of total female flower/fruit to total male flower tree.
14.	Reproductive status	Presence or absence of flowers and/or fruits.

Data analysis

Pearson's correlation analysis was used to analyse the association between reproduction (onset of flowering) and climatic variables. Analysis of variance (ANOVA) was used to analyse climatic variation between reproductive seasons and seasonal variations of flowering intensity. T-tests were used to analyse flowering intensity variation between dry and wet seasons.

RESULTS

Onset and duration of reproductive rest

Generally, reproductive rest (Fig. 1) lasted 3 months in the plantation and was usually characterized by low intensity of flowering (Table 1) or the complete absence of flowers on the trees:

Rest duration of female trees

The onset of reproductive rest for female trees varied for individual trees from

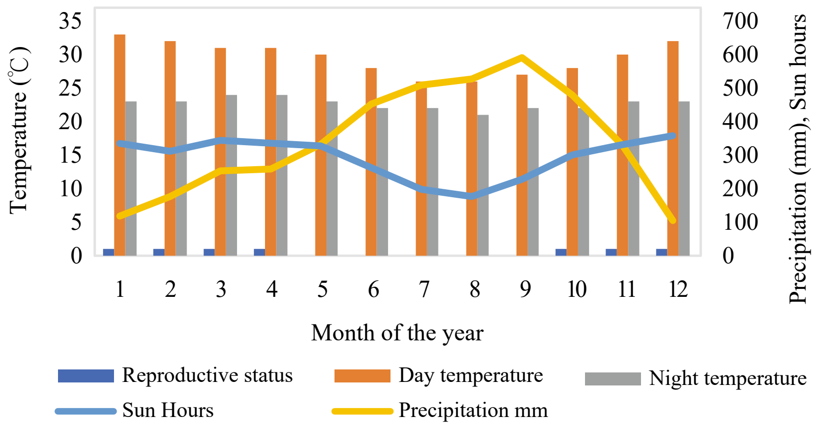

Fig. 1. Relationship between reproductive status of *G. kola* and mean climatic variables in a humid forest plantation. *Reproductive status = presence of flowers or fruit.

Table 1. Mean flowering intensity variation between dry and wet seasons

Dry Season			Wet Season		
Male	Female	Hermaphrodite	Male	Female	Hermaphrodite
9 ± 7	2 ± 1	9 ± 5.8	19 ± 1.53	7 ± 5.51	16 ± 3.5

Table 2. T-test analysis of flowering intensity variation between dry and wet seasons

Tree gender	Std. err	t-stat	df	*p*-value	t-critical
Male	4.136558	2.498051	2.190045	0.118969	3.963935
Female	1.054093	4.427189	3.448276	0.015902	2.96073
Hermaphrodite	3.944053	1.774824	3.272667	0.166317	3.037579

**$p \leq 0.05$ = significant.

May to August and lasted for three months (Fig. 1). The pattern of reproductive rest in female trees was such that flowering intensity reduced significantly from 7 ± 5.51 to 2 ± 1 flowers per inflorescence (Tables 1 and 2), however, the trees were never at any time without flowers. Towards the end of the rest period was the only time that fruits did not occur together with flowers on a female tree. During this period reduced intensity of flowering results in a fruiting gap with few flowers or fruits on the trees and under the mother trees.

Rest duration of male trees

Male trees in the plantation were always bearing flowers, such that old and new flowers were always present on the trees. Like the female trees, the flowering intensity of male trees slowed from 19 ± 1.53 to 9 ± 7 flowers per inflorescence (Table 1) during the rest period. This reduction was observed consistently from May to August (Fig. 1) for individual trees. Male trees showed their inconstant behavior mostly during the rest period when very few (0.0001%) female flowers and fruits were found on the trees.

Rest duration of hermaphrodite trees

The behavior of hermaphrodite trees was intermediate to both female and male trees. Hermaphrodite trees produced fruits towards the beginning of the rest period (May-August, Fig. 1) like the inconstant male trees, but unlike the female trees that slowed flowering intensity. Some hermaphrodite trees mirrored the behavior of female trees; slowing flowering intensity from 16 ± 3.5 to 9 ± 5.8 flowers per inflorescence (Table 1).

Climatic cues for the onset of reproductive rest in the plantation

Generally (across all tree genders), reproduction was strongly positively correlated with night temperature ($r = 0.66$), day temperature ($r = 0.76$), and hours of sunshine ($r = 0.78$) but showed a strong negative correlation with precipitation ($r =$

Table 3. Correlation coefficients of reproductive status of plantation vs climatic variables.

Climatic variables	*r**
Day temperature (℃)	0.76
Night temperature (℃)	0.66
Rain days	-0.49
Precipitation (mm)	-0.73
Sun hours	0.78
Sunny days	0.45

*r = correlation coefficient; -1 = negative correlation; +1 = positive correlation.

0.73) (Table 3). Consequently, reproductive rest onset was associated with months of high rainfall and low temperatures in the plantation (May-August) (Fig. 1). Due to significant differences ($p \leq 0.05$) in rainfall patterns (Table 4), indicating significant rainfall variability (Fig. 2) between the reproductive seasons, the onset of reproductive rest in the plantation was not consistent throughout the study period but rather fluctuated between May and August (Fig. 1).

Reproductive onset (emergence of flower buds)

The emergence of flower buds on the previously flowerless trees marks the onset of reproduction. The initiation of flower bud development as well as the onset and the duration of the entire reproductive season correlated strongly positively with night temperatures (r = 0.66), day temperatures (r = 0.76) and hours of sunshine (r = 0.78), but correlated strongly negatively with precipitation (r = -0.73) (Table 3). Consequently the emergence of flower buds and the reproductive season in the *G. kola* plantation was therefore associated with increased average temperatures, sunshine hours, and reduced precipitation (November-April) (Fig. 1). Flower buds initiated at least once a month throughout the reproductive season.

Table 4. ANOVA climatic variations of three reproductive seasons of *G. kola* in a humid forest plantation.

Sources	SS	df	MS	F	*p*-value
Day temperature (℃)	4.087	2	2.043	0.447	0.643
Night temperature (℃)	0.227	2	0.114	0.178	0.838
Pressure (mb)	2.842	2	1.421	0.493	0.615
Humidity (%)	18.024	2	9.012	0.040	0.961
Precipitation (mm)	85308.31	2	42654.16	3.875	0.031*
Visibility (km)	3.699	2	1.850	1.269	0.295
Wind speed (kmph)	236.22	2	118.11	6.223	0.005*

** = significant at $p \leq 0.05$. Season 1 (2018/19), Season 2 (2019/20), Season 3 (2020/21).

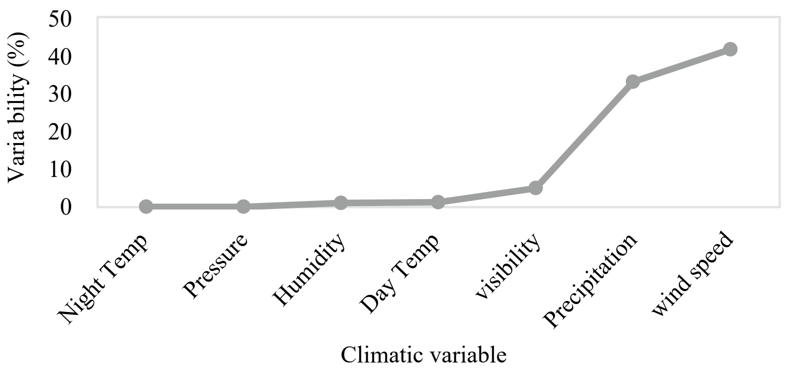

Fig. 2. Variability of climatic variables across flowering seasons (2018/19; 2019/20; 2020/21)

Flower bud initiation and duration

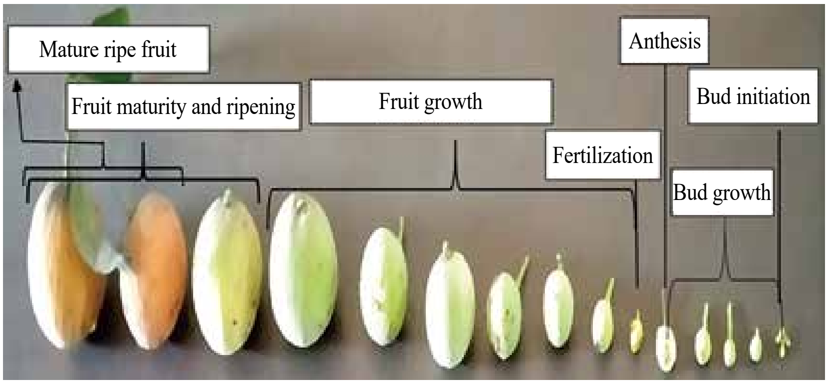

Fig. 3. Reproductive phenoevents of *G. kola* in a humid forest plantation.

Fig. 4. Receptive *G. kola* stigma with a glossy (sticky) surface. A. Female flower; B. Bisexual

Fig. 5. Fertilized *G. kola* female flower stigma with brown surface.

Flower bud growth and duration

Following initiation, flower bud growth through pre-anthesis lasted 6 to 8 weeks (Fig. 3). During this period, buds grew from an initial mean size of 4.2 ± 1.1 mm to 11.7 ± 3.1 mm.

Anthesis and fertilization

Anthesis (bud opening) and fertilization lasted between 3 to 4 weeks (Fig. 3) and was characterized by the female flower stigma becoming moist and sticky (Fig. 4); fertilized flowers had a brownish stigma surface (Fig. 5).

Fruit maturity

The period from fertilization through fruit maturity and ripening lasts 6 to 8 weeks. Mature fruits change color from green to reddish yellow (Fig. 6). If not picked, ripe fruit fall to the ground and accumulate as litter under female trees.

Reproductive season and flowering cycles

The nine month (August to April) (Fig. 1) long reproductive season in the plantation consists of 3 to 4 flowering cycles that overlap in such a way that buds, flowers, and fruits are always present on the female trees throughout the season. Flowering intensity varied slightly between cycles; the first flowering cycle after the reproductive rest period was usually the highest while flowering intensity diminished towards the drier months (November to April) (Fig. 1). Mean flowering intensity in the first

Fig. 6. Shades of fruit colour at maturity of *G. kola* in a humid forest plantation.

Table 5. T-test analysis of seasonal variation in number of flower buds/inflorescences

	Std err	t-stat	df	*p*-value
One Tail	3.187	1.88	14	0.040
Two Tail	3.187	1.882	14	0.081

*$p \geq 0.05$ = not significant; $p \leq 0.05$ = significant.

cycle was 16 buds, while the average for the drier months was 10 buds per inflorescence; a t-test analysis of variation of number of buds between the wetter and drier seasons revealed significant differences ($p \leq 0.05$) (on one tail) in flowering intensity between the two seasons (Table 5). However, there were no significant differences ($p \geq 0.05$) in flowering intensity between the three flowering seasons (2018/19, 2019/20, and 2020/21) (Table 6; Fig. 7).

Table 6. ANOVA seasonal variation of flowering intensity in *G. kola* in Onne

Sources	SS	df	MS	F	*p*- value
Male trees	140.667	2	70.333	0.743	0.503
Female tree	1.951	2	0.976	2.853	0.11
Hermaphrodite	84.5	2	42.25	1.671	0.241

*$p \geq 0.05$ = not significant.

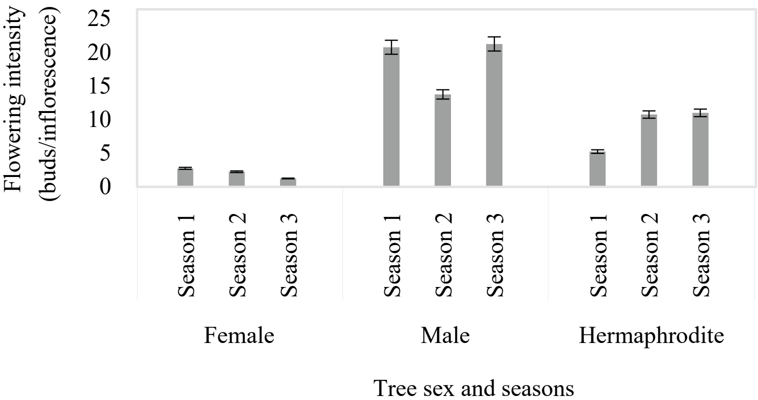

Fig. 7. Seasonal variation of flowering intensity of *G. kola* in a humid forest plantation

DISCUSSION

The onset of reproductive rest in the *G. kola* humid forest plantation correlated strongly negatively with rainfall (r = -0.73); while night temperature (r = 0.66), day temperature (r = 0.76), and sunshine hours (photoperiod) (r = 0.78) correlated strongly positively with reproduction (flowering/fruiting), establishing that the climatic cues for reproduction (flowering) in the plantation are temperature and sunshine hours (photoperiod). This contrasts with the general consensus that rainfall was the reproductive cue of tropical species (Borchert 1998, Morellato et al. 2000, 2013).

Keay et al. (1964) reported the *G. kola* range in Nigeria to be from the rainforests of south-west and south-east to the humid forests of the coastal areas of the south. In the same vein, Agwu et al. (2020) showed that *G. kola* thrives mainly in the rainforests and humid forest areas. These two studies investigated the natural range of *G. kola* and confirm that our study plantation is clearly within the reported range of the species in the wild. Furthermore, Onyekwelu et al. (2015) failed to find *G. kola* in the derived savannah in an assessment of fruits trees of the rainforest and derived savannah in Ondo State of Nigeria. Whereas Keay et al. (1964) reported that *G. kola* exhibits a seasonal reproductive phenology; that is, that the species flowers from December to January and fruits from July to October. Our findings show that the reproductive phenology of *G. kola* in a humid forest plantation is not seasonal; rather the trees in our plantation bore flowers and fruits all year round and only showed a reduction in flowering intensity at certain months of the year which varied from May to September; flowers may be absent during the reproductive rest months but fruit are sometimes present.

G. kola trees in the plantation exhibited sexual dimorphism in the pattern of onset of reproductive rest and relative growth rate of flower buds. The dimorphic behaviour of the sexes may be attributed to gender variation in resource demand. Female *G. kola* trees are reported to allocate more resources to reproduction than males and hermaphrodites (Okonkwo et al. 2022). This suggests that climate change may affect different genders differently in the trioecious plantation. Furthermore, climate warming might trigger changes in the frequency of occurrence of sexes or even the evolution of sexual systems most suited to the prevalent climate. This hypothesis is supported by the presence of inconstant male and hermaphrodite trees in the *G. kola* humid forest plantation, which are evidence of a dynamic sexual system (Okonkwo et al. 2022). For example, the sexual system of our study *G. kola* plantation was trioecious. Almost 6 decades ago, Keay et al. (1964) reported that *G. kola* in Nigeria was androdioecious. According to the World Bank Group, Climate Change Portal (2023) historical climate data, mean minimum monthly temperature has risen by 0.48℃, maximum temperature by 0.35℃, and rainfall by 6.3 mm in Nigeria over the last 59 years. This suggests that the rise in temperature, sunshine hours and rainfall could have contributed to the evolution of the sexual system from androdioecious to the present trioecious. Although other ecological factors such as nutrient availability and even mutation may also be responsible.

We found that flowering intensity during the drier months was lower than during the wetter months in the plantation, which is indicative of rainfall being important to flower and fruit production in the plantation. Specifically, rainfall influenced the total number of flowers produced and hence fruit production. Rainfall is reported to influence fruit production in several species (Okullo et al. 2004, Berjano et al. 2006, Glele Kakai et al. 2011), indicating that climate warming is affecting flowering and fruit production (Bhattacharjee et al. 2022) in the studied plantation.

CONCLUSION

The reproductive phenology of *G. kola* in the humid forest is mediated by rainfall, sunshine hours (photoperiod), and temperature. Since, the plantation reproduces all year round, rests towards the slowing of the rains and begins the reproductive season with rising temperatures, this paints the picture of a plantation whose reproductive phenology is intricately controlled by rainfall, sunshine hours and temperature. The reducing flowering intensity of the trees during the drier months of reproduction shows the effect of rainfall on the quantity of flowers and fruits production in the plantation. Since, this is an ongoing study, we hope to further study the interplay of rainfall, sunshine hours, and temperature on the phenology of this evergreen multipur-pose tree species.

LITERATURE CITED

Agwu OP, Bakayokoa A, Jimoh SO, Porembski KD. 2020. Impact of climate on ecology and suitable habitat of *Garcinia kola* (Heckel) in Nigeria. Trees, For. and People, 1, 100006.

Berjano R, De Vega C, Arista M, Ortiz PL, Talavera S. 2006. A multiyear study of factors affecting fruit production in *Aristolochia paucinervis* (Aristolochiaceae). Am. J. Bot. 93:599-606.

Bhattacharjee P, Warang O, Das S, Das S. 2022. Impact of Climate Change on Fruit Crops: A Review. Curr. Worl. Environ. 17(2). DOI:10.12944/CWE.17.2.4

Borchert R. 1998. Responses of tropical trees to rainfall seasonality and its long-term changes. Clim. Chang., 39:381-93.

Borchert R, Renner SS, Calle Z, Navarrete D, Tye A, Gautier L, et al. 2005. Photoperiodic induction of synchronous flowering near the Equator. Nat 433:627-29.

Bradley AV, Gerard FF, Barbier N. 2011. Relationship between phenology, radiation and precipitation in the Amazon region. Glob. Chang. Biol. 17:2245-60.

Glèlè Kakaï R, Akpona TJD, Assogbadjo AE, Gaoué OG, Chakeredza S, Gnanglè PC, et al. 2011. Ecological adaptation of the Shea butter tree (*Vitellaria paradoxa* C.F. Gaertn.) along climatic gradient in Bénin West Africa. Afr. J. Ecol. 49:440-9.

IPCC 2014. Climate Change. Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

Isawumi AM. 1993. The common edible fruits of Nigeria, Part II. The Nigerian Field, 58:1-2.

Keay RWJ, Onochie CFA, Stanfield DP. 1964. Nigerian Trees. The Nigerian National Press Ltd, Ibadan, pp. 185-6.

Manourová A, Leuner O, Tchoundjeu Z, Van Damme P, Verner V, Pribyl O, et al. 2019. Medicinal potential, utilization and domestication status of Bitter kola (*Garcinia kola*) in West and Central Africa. For. 10:124.

McLaughlin ÃR., Morellato LPC, O'Gorman EJ, Trøjelsgaard K, Tylianakis JM, Vidal MM, et al. 2012. Biodiversity, species interactions and ecological networks in a fragmented world. Adv. Ecol. Res. 46:89-210.

Mendoza I, Peres CA, Morellato LPC. 2017. Continental-scale patterns and climatic drivers of fruiting phenology: a quantitative Neotropical review. Glob. Planet Chang. 148:227-41.

Morellato LPC, Camargo MGG, Gressler E. 2013. A review of plant phenology in South and Central America. In: Schwartz, M.D. (Ed.), Phenology: An Integrative Environmental Science (pp. 91-113). The Nederland, Springer.

Morellato LPC, Talora DC, Takahasi A, Bencke CC, Romera EC, Zipparro VB. 2000. Phenology of Atlantic rain forest trees: a comparative study. Biotropica 32:811-23.

Newstrom LE, Frankie GW, Baker HG. 1994. A new classification for plant phenology based on flowering patterns in lowland tropical rain forest trees at La Selva, Costa Rica. Biotropica 26:141-59.

Okonkwo HO, Omokhua GE. 2022. Sexual system, sexual polymorphism and resource partitioning in a *Garcinia kola* (Heckel) population at Onne, River state Nigeria. J. For. Sci. Environ. 7:49-55.

Okonkwo HO, Ejizu AN, Eric EE. 2020a. Assessment of pre-germination treatment methods for reducing *Garcinia kola* (Heckel) seed dormancy and its germination characteristics dynamics. Afri. J. Agric. Technol. Environ. 9:245-56.

Okullo JBL, Hall JB, Obua J. 2004. Leafing, flowering and fruiting of *Vitellaria paradoxa* subsp. nilotica in savanna parklands in Uganda. Agrofor. Syst. 60:77-91.

Onyekwelu JC, Oyewale O, Stimm B, Mosandl R. 2015. Antioxidant, nutritional and anti-nutritional composition of *Garcinia kola* and *Chrysophyllum albidum* from rainforest ecosystem of Ondo State, Nigeria. J. For. Res. 26:417-24.

Rivera G, Borchert R. 2001. Induction of flowering in tropical trees by a 30-min reduction in photoperiod: evidence from field observations and herbarium specimens. Tree Physiol. 21:201-12.

Rosemartin AH, Crimmins TM, Enquist CAF, Gerst KL, Kellermann JL, Posthumus EE, et al. 2014. Organizing phenological data resources to inform natural resource conservation. Biol. Conserv. 173:90-7.

Rosenzweig C, Karoly D, Vicarelli M, Neofotis P, Wu Q, Casassa G, et al. 2008. Attributing physical and biological impacts to anthropogenic climate change. Nat. 453:353-7.

Sakai S. 2000. Phenological diversity in tropical forests. Popul. Ecol. 43:77-86.

World Bank Group, Climate Change Knowledge Portal 2023. Available at: https://climateknowledgeportal.worldbank.org/. Accessed 2023 October 16.